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by

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INTRODUCTION.

The present paper describes the results of an investigation into the cause of a skin disease of sheep in South Australia. A preliminary communication was made earlier in the year (2). When this investigation was started in September, 1928, there was nothing in the literature to indicate that the disease had been described from any part of the world. Since then Bekker (1) has described, under the name "lumpy wool," a condition observed quite commonly in South Africa in many parts of the Union. It makes its appearance sporadically in merino sheep. Hard pyramidal masses, formed by an exudate into the wool, are found on the dorsal aspect of the body. Attempts to establish the cause of the condition and to reproduce it artificially have failed. It is regarded as of considerable economic importance, as much wool may be damaged, and in some cases the general health of the animal be impaired. It is possible that the condition described by Bekker has the same etiology as that found in this State. Seddon (3) has described a similar condition in sheep in New South Wales. It was found in several widely separated localities. Seddon has succeeded in conveying the disease to healthy sheep under experimental conditions. An opportunity occurred in May last of seeing some of these experimental animals and some of the specimens collected in the field. The opinion was reached that the condition under investigation in New South Wales is probably identical with that observed in this State.

From time to time specimens of matted wool have been submitted for an opinion as to the probable cause of the condition. No definite information was obtained from macroscopic or microscopic examinations of these specimens. Later, opportunity occurred of examining in the field animals showing a matted

condition of the wool and of keeping some affected animals under observation in the laboratory. Experimental and bacteriological examinations have been conducted, and the results of these examinations are given below.

Clinical and Field Observations.

Most of the affected animals examined have shown numerous small areas of densely matted wool scattered irregularly over the back, the sides, and the upper-surface of the neck. Usually the ears, face, legs, and under-surface of the body are quite free from any lesions. In a few instances small lesions have been observed about the nose and lips. In one exceptional case (sheep L. 1) there were extensive lesions about the face and ears, as well as on other parts of the body. This animal was kept under observation at the laboratory for some time, and a more detailed description of the lesions in this case will be given below.

The matted wool is attached very firmly to the skin, the areas affected being roughly circular, and varying in diameter from slightly less than a quarter of an inch to about 1 inch. For the most part these areas are discrete, but sometimes two or more may be situated closely together and coalesce. The matted condition of the wool extends up along the fibre for about an inch to an inch and a half. In exceptional cases the matted condition may extend throughout the whole length of the staple. These masses cannot be removed from the skin except by cutting with scissors or other sharp instruments, when some damage to the skin results, particularly around the periphery, where adhesion is greatest. The skin beneath is found to be raw-looking. The mass of matted wool is found to be concave on its proximal surface, due to contraction of the centre, and the binding together of the wool fibres is found to have resulted from an exudation from the skin which has dried into a dense, tough mass. In exceptional cases the mass may be removed from the skin by moderate traction, leaving a dry but otherwise normal-looking skin beneath.

Only young animals have been found to be affected. The condition has been observed at shearing time, when it has been found impossible to pass the shears through the matted areas. On one property, M.L., summer lambs, about seven or eight months old, were found most severely affected, while the previous season's lambs, sheep of about eighteen months old, were less severely affected. Older sheep, even when running with the younger, affected sheep, have not shown the presence of any lesions. Sixteen out of 60 summer ewe lambs (26%) and 22 out of 200 eighteen months old ewes (11%), were found to be affected. On another property, L., about 10% of the young ewes were affected.

Field observations were confined to the sheep on these two properties in the same district, about 130 miles north of Adelaide, and separated from one another by a distance of about 3 or 4 miles. The two flocks were quite distinct, and there had never been any contact between them. Both flocks were stud merinos,

one a fine wool type and the other a stronger wool type. In the one instance only an odd animal had been affected during the previous four years, and in the other one ewe was found with the disease three years previously, but it had been destroyed. From the depth of the exudate in the wool one judges that the condition had started about a month or so before shearing, that is, during June or July, and when the animals were seen in the latter part of September there was distinct evidence that the lesions were clearing up in the majority of the animals, normal, clean wool pushing the matted wool away from the skin.

One animal of the stronger wool type and two from the other stud were kept under observation at the laboratory. One of the animals (sheep L. 1) from the latter stud showed the disease in an advanced and severe form. The exudate extended throughout the whole length of the staple, showing that the condition had progressed during the major portion of the year. The animal was two and a half years old, the only animal over eighteen months old found affected in either stud. The skin and wool on the back of the animals was very extensively involved, some of the areas being 4 or 5 inches in diameter. Wart-like masses were crowded together over the nose, and extended downwards to the corners of the mouth and under the chin (*vide* figure 1). The external ears were also affected and eroded along the margins. Some of the matted wool could be removed easily from the skin, leaving a dry but otherwise normal-looking skin beneath. The animal was kept under cover, but the condition was progressive. Large masses of matted wool came away from the lumbar region, leaving a thick, dry, rough, and scaly mass attached to the skin. Lesions developed on the legs as far as the hoofs, and those on other parts of the body enlarged. There was, however, no involvement of the ventral surface. The animal became emaciated, and died towards the end of January.

The other animal from the same stud, a ewe lamb (sheep L. 2), has also shown a progressive condition, with an exudate through the whole length of the staple at the time of writing, after being under cover and under observation for twelve months. Lesions have also appeared about the upper lips (*vide* figure 2). The lesions about the trunk have not increased very much in diameter, although the exudate has been continuous, and, as far as can be judged, new lesions have not developed about the trunk. The dorsal surface is comparatively free from lesions, most of them being situated along the sides of the thorax and the flanks. The ventral surface remains free from any lesions.

The stud M.L. was transferred to another State, and no information has been received as to the health of the animals.

There has been little recurrence of the disease this year in Stud L. No prophylactic measures have been adopted. Three thousand sheep have been shorn, and only six very slightly affected animals have been detected. Possibly the droughty conditions were responsible for the low morbidity. The rainfall

in the district in the years 1928 and 1929 over a period of four months is set out below:

	1928.	1929.
May	208 points	139 points
June	258 „	162 „
July	216 „	117 „
August	49 „	132 „

It will be seen that 682 points fell in the May–July period in 1928, and 418 points during the same period in 1929. It is possible that the difference of 264 points was responsible to some extent for the low morbidity.

Experimental Transmission.

The first attempt to reproduce a lesion in a healthy animal was made by removing a mass of matted wool from the skin of an affected sheep and rubbing the base of this mass over a small area of skin on the nose of a healthy three years old merino ram. The area inoculated was lightly rubbed with a scalpel until a slight exudate appeared, after which the base of the mass of matted wool was rubbed over the area. On the following days an increasing swelling of the skin, with the accumulation of a dried exudate, developed. The reaction produced was only transitory. A scab about a quarter of an inch thick developed, but was pushed off by the growth of wool in about three weeks' time.

Two other areas of skin in the same animal were inoculated, one on the forehead, where the wool had been clipped with scissors, and the other on the sides of the thorax, where the wool was merely parted. In neither instance was the skin scarified. The same transient reaction occurred, with matting together of the wool by exudate.

These experiments were repeated on the same ram, and another ram of the same age, using material from affected lambs from both the studs mentioned. In every case the same type of reaction was produced following the application of the base of a freshly removed mass of matted wool to the uninjured skin.

Two merino lambs were used for the same type of experiment, the wool being parted and the skin rubbed with the base of a freshly removed mass of matted wool from an affected animal. In no case was the rubbing severe enough to produce any macroscopic damage to the skin of the experimental animal. In from 48 to 72 hours an exudate had occurred into the wool covering the part inoculated. The exudate continued to increase for a week or ten days, matting the wool together to a depth of about a quarter of an inch or slightly more. The reaction ceased after a period of from ten days to a fortnight, and with the growth of the wool the matted areas were pushed off the skin. The reaction produced was somewhat more severe than that produced in the older animals, but not as severe as that found under natural conditions.

Microscopic examinations of the matted wool had shown the presence of numerous squamous epithelial cells and leucocytes, as well as a short, branching

mycelium. The mould-like micro-organism had been isolated, and pure cultures were used in transmission experiments.

An experimental lamb (merino) was sprayed with water from a hose until the fleece was soaked, on two consecutive days. On the third day three lesions were removed from an affected lamb, and the base of each ground up in a mortar with sterile saline. This emulsion and a culture of the micro-organism, consisting of a mixture of a 24 hours and a 48 hours old culture in glucose broth were taken for the purpose of inoculation. In one area the culture was applied to the skin after parting the fleece. In another area the culture was applied to the wool about one-half to three-quarters of an inch from the skin. The culture was also applied to the skin of the groin after it had been cleaned with alcohol. Three more areas on the opposite side of the animal were treated in the same way with the emulsion. In 24 hours the skin of both groins showed slight, patchy erythema and thickening, which increased in the next 24 hours, with the appearance of minute pustules. During the following days the pustules became large, although quite superficial, the skin increased in thickness, and scabs occurred. The maximum reaction was reached in seven days, but quickly subsided, with complete resolution in the next four or five days. Lesions also developed in those areas where the emulsion was applied to the skin and to the wool, the reaction being slighter in the latter case. No lesion developed in the area where the culture was applied to the wool, but a typical lesion, with cupping of the centre of the base, developed where the culture was applied directly to the skin. These experiments were carried out in January, when the weather was hot. The fleece of the animal quickly dried under the warm and dry atmospheric conditions. A more severe and prolonged reaction might be anticipated where atmospheric conditions favour an optimum condition of moisture in the fleece over a longer period.

Cultures and emulsions of the exudate from affected animals have been applied to the uninjured skin of sheep on many occasions, but the results have not differed from those outlined above, so reiteration is unnecessary.

Microscopic examinations of the exudate and pus from the pustules produced in experimental animals have shown the presence of the micro-organism.

Under natural conditions no lesions have been observed on the ventral surface of sheep, and only in one instance have they been found on the limbs. Experiments were made to determine if the skin over certain parts of the body is more resistant to invasion by the micro-organism than that over other parts. A lesion was removed from an affected lamb (sheep L. 2), and emulsified. The emulsion was applied to the skin of the forehead, the skin on the inside of the thigh, and to the skin on the abdominal wall of the same animal, all these areas being free from natural lesions. An experimental lamb was inoculated with the same emulsion in the corresponding areas. The experimental lamb developed the usual transient lesion on the forehead, but none on the thigh or abdomen.

The same result was obtained in the affected animal except that the lesion on the forehead was severe and progressive. The lesion is still active, over three months after inoculation.

A similar experiment was made, using both emulsion and culture. The same affected lamb as used in the previous experiment received an application of emulsion to the skin of the right thigh, and a few inches lower down, to the skin which had been lightly scarified. On the left thigh an area of skin was rubbed with a 24 hours old culture of the micro-organism in broth, and a few inches lower down 0·2 cc. of the same culture was injected subcutaneously. The same inoculations were carried out on an experimental lamb. No reaction was produced, except from the subcutaneous inoculation of culture in the experimental lamb, where a nodular swelling developed in 24 hours, which had slightly decreased in the next 24 hours. There was no breaking down of the tissues and the swelling gradually disappeared. The affected lamb showed in 24 hours a slight induration where the culture had been injected, but it had almost disappeared 48 hours after inoculation. A slight reaction occurred where the skin had been lightly scarified before the application of emulsion, but none in the other areas.

These two experiments indicate that the skin covering the ventral surface of the body and the legs is relatively resistant to invasion by the micro-organism, and, further, that the subcutaneous tissues of an affected animal appear to develop some resistance to the micro-organism. In view of this local immunity of the skin covering the ventral surface of the body and the limbs, the production of lesions on the galbrous skin of the groins may seem to be contradictory and difficult of explanation. The explanation is probably to be found in the fact that the applications of cultures of the micro-organism or emulsion of lesions to the skin of the groins were made after the skin had been thoroughly cleaned with alcohol. This procedure completely removed the coating of yolk, which is usually very thick over the skin of these parts, and with it probably some of the superficial epithelial cells, rendering the epidermis more vulnerable. That this is not a complete explanation is suggested by the failure to produce anything more than a slight reaction in the skin of the thigh after light scarification. It seems reasonable to conclude, therefore, that the thin skin over the groins is less resistant than the thicker skin over the thighs.

The experiments have demonstrated that the severity of the reaction to the invasion of the skin by the micro-organism depends very largely on the individual susceptibility of the animal. Using a susceptible animal (sheep L. 2), a severe lesion was produced by applying an emulsion of a lesion to the uninjured skin of the forehead. This lesion has progressed, and is still active three months after the inoculation. This reaction is more severe than that usually found under natural conditions.

The result of one experiment indicates that the micro-organism probably

grows in the fleece when there is sufficient moisture present, and that the skin may be invaded and a lesion produced under such circumstances.

An experiment was conducted for the purpose of demonstrating if contact of healthy with affected animals would lead to infection of the skin and the production of lesions. Two wethers were placed in the same pen with two affected animals (sheep L. 1 and sheep L. 2) on October 3, 1928, and kept under cover. On January 4, 1929, these two wethers and a lamb were sprayed with water from a hose until the fleece was thoroughly saturated. The hosing was repeated on the following day, and the animals returned to the pen with the affected sheep. The affected ewe from the other stud (sheep M.L. 1), was also placed in the same pen. The animals were examined from time to time, but no lesions could be detected on the experimental sheep. Sheep L. 1 died towards the end of January, and sheep M.L. 1 improved, normal wool pushing the matted areas away from the skin. On June 18, 1929, the experimental animals and sheep M.L. 1 were placed outside under natural conditions. Light showers of rain fell during the day, and again on the 20th. On the 21st more showers developed, with heavy rain in the afternoon. There was little rain after this until July 4, when a heavy shower occurred. July and August were unusually dry months. The sheep were shorn towards the end of August, and no lesions could be found on any part of the body.

The result of this experiment indicates that the disease is not easily conveyed from one animal to another, even under conditions of close contact over a period of ten months.

Antiseptic and Germicidal Action of Various Substances.

The effect of salicylic acid, sodium hyposulphite, and flowers of sulphur in preventing the development of lesions under experimental conditions was investigated.

A merino lamb was taken, and half the staple of wool was removed from an area about 3 inches square. To this area, and to an unclipped area of the same size, a 1 in 1,000 salicylic acid solution in water was applied, saturating the wool. The following day a small section of skin in these two areas was rubbed with the base of a matted mass of wool from an affected animal. Three other areas were inoculated in the same way, one being treated immediately afterwards with a 5% aqueous solution of sodium hyposulphite, another with flowers of sulphur, and the third left as a control. Lesions developed in all the areas inoculated, but the reaction was slightly inhibited by both the sulphur and the sodium hyposulphite.

The inhibiting action of copper sulphate was next tested. A 1 in 1,000 copper sulphate solution in water was swabbed over the skin of the right groin. The skin was lightly dried, and an emulsion of a 48 hours old culture was applied to the surface. The skin of the left groin was treated with the culture as a

control. An area in the right flank was treated with the same copper sulphate solution, and the excess swabbed out of the wool with dry swabs. This area and a control area on the opposite flank were treated with culture. The control areas developed typical reactions, and a few small pustules also developed in the right groin. No reaction developed in the flank treated with the copper sulphate solution. The result of the experiment indicates that sufficient copper sulphate may not be held on the glabrous skin to prevent invasion by the micro-organism, but in a part covered by wool sufficient may be held to prevent the development of the micro-organism and the invasion of the skin. The massive inoculation by the use of a culture of the micro-organism makes this a severe test, so that the results must be regarded as favourable.

In vitro Tests. Tests were carried out by adding 0·1 cc. of a 48 hours old broth culture (broken up by shaking) of the micro-organism to 5 cc. quantities of the substances to be tested in aqueous solution. Subcultures were made after the lapse of five minutes. A 1 in 100 dilution of salicylic acid was found to possess no germicidal properties under the conditions of the test. The action of iodine, copper sulphate, mercuric chloride, and sulphurous acid was determined, and is summarized in the following table:

	Dilution						
	1:1000	1:2000	1:4000	1:8000	1:16000	1:32000	1:64000
Iodine	—	—	—	—	—	+	+
Copper sulphate	—	—	—	—	+	+	+
Mercuric chloride	—	—	—	—	—	—	+
Sulphurous acid (SO_2)	—	—	+	+	+	+	+

— = No growth; + = growth on subculture.

The solution of iodine was made by taking 1 part of iodine, 2 of potassium iodide, and 100 of water.

The sulphurous acid was made by diluting the B.P. preparation, which was taken to contain 5% of SO_2.

The copper sulphate solutions were made from the crystalline salt, so that for the purpose of comparison the dilutions should be $^{25}/_{16}$ of the actual figures given. If this correction is made it will be seen that mercuric chloride is 2·56 and iodine 1·28 times as germicidal as copper sulphate under the conditions of the test.

As copper sulphate is easy to obtain, relatively safe to use, and inexpensive, it should prove suitable for use under field conditions.

Field and experimental observations have indicated that the micro-organism probably grows in the fleece when conditions of moisture are favourable, and that the skin is subsequently invaded. The disease appears to be seasonal, occurring during the winter. It is recommended, therefore, that for the purpose of prevention, young animals should be dipped in a 1 in 500 copper sulphate solution towards the end of autumn, and again a month later, particularly where the disease is troublesome.

The Nature of the Lesion.

In the early stages the lesion is essentially exudative in character. A sero-fibrinous fluid with a moderate number of leucocytes exudes from the surface of the skin, and is absorbed by the overlying wool. This gradually dries, matting the wool fibres together, and forming a dense and tough mass. The exudation continues as long as the lesion remains active, but in the later stages it becomes mixed with a relatively large number of squamous epithelial cells from the surface of the skin. Chronic lesions become less exudative and more keratogenous or desquamative.

In the majority of cases the inflammatory reaction ceases, and the infection is overcome in from one to three months. In these mild cases all the lesions present appear to be of about the same age, and they do not tend to enlarge. In the chronic cases where the lesions may remain active for twelve months or more there is some increase in size of the individual lesion by an extension at the periphery as well as the production of new lesions in other parts of the body. The wool fibre does not appear to become involved, nor is there usually any involvement of the wool follicle as the wool remains firmly attached to the skin. In the later stages there is involvement of the wool follicle, the wool fibre coming away from the skin, particularly in the centre of a lesion. In the chronic lesion the growth of the wool fibre may be arrested, and the whole mass of matted wool come away from the lesion beneath.

A microscopic examination of a section of the skin from a chronic lesion shows the cornified layer to be diffusely invaded by neutrophile polymorphonuclear leucocytes. There is vesiculation of the epithelium in the more superficial parts of the *rete mucosum*, the vesicles becoming invaded early by polymorphs. In some parts the epithelial layer may be thin, and vesiculation lead to its almost complete destruction. There may be accumulation of polymorphs about the exit of the wool fibre, but the reaction is not particularly associated with the follicles. There is slight diffuse invasion of the middle layer of the *rete mucosum* by polymorphs, but for the most part the basal cells remain unaffected. In the *cutis vera* beneath the epidermis, and surrounding the follicles, there is a well-developed accumulation of lymphocytes and plasma cells, with an occasional polymorph. Sometimes there are areas of oedema between the follicles, with some haemorrhagic extravasation. The crusts attached to the epithelium are found to consist of keratinized epithelial cells and polymorphs bound together by a sero-fibrinous exudate. In the crusts and in the superficial epithelium are found collections of a branching mycelium. The strands of mycelium are short, and there are many bacillary forms present. Some of the mycelial threads show the development of conidia, which appear to be somewhat compressed vertically. As well as occurring in definite collections, the mycelium, usually in bacillary form, is seen diffusely and irregularly scattered through the superficial parts of the epidermis. In a chronic lesion the *corium* may be invaded, and bacillary

forms are seen sparsely scattered in and around the oedematous areas. For the most part, however, the invasion is confined to the epidermis, and may be purely superficial.

The Micro-organism.

The micro-organism has been cultivated with ease on many occasions, and usually unassociated with other moulds or bacteria. The same micro-organism has been isolated from the lesions of affected sheep from the two studs mentioned above.

Morphology. In the dried exudate from the skin of spontaneous cases of the disease the micro-organism is seen to be present in the form of a branching mycelium, as well as in short, bacillary form. The branching is lateral, the side branches being short and usually somewhat thinner than the main trunk. The mycelium varies in diameter from under $0{\cdot}5\,\mu$ to about $1\,\mu$. With the development of conidia the diameter commonly reaches $1{\cdot}75\,\mu$. The conidia, which are best studied in stained films of cultures, vary considerably. When stained by Gram's method they are found to vary in diameter from below $0{\cdot}5\,\mu$ up to about $1{\cdot}75\,\mu$. The bacillary forms vary in length from about $1{\cdot}8\,\mu$ to $4{\cdot}5\,\mu$, the most common form being $3{\cdot}6\,\mu$ in length. They are often thickened at one end, and somewhat wavy in outline. Sometimes they are bent almost at a right angle at the thickened end, and slightly curved, the general appearance resembling that of a horse-shoe nail. These forms are more frequently seen in cultures. The development of conidia is more abundant in rapidly growing cultures. The main mass of such a culture appears to consist of cocci mixed with some mycelial threads undergoing transformation into conidia, and giving a streptococcal appearance. The mycelium is somewhat thinner at its growing end.

Staining Reactions. The micro-organism stains well with the ordinary aniline dyes, and retains Gram's stain strongly. The staining may be somewhat irregular, particularly in the material from lesions. The conidia also retain the Gram's stain strongly. It is not acid-fast, nor does it retain the fuchsin when decolourization is done with a saturated alcoholic solution of picric acid (Plaut's stain).

Cultivation. It grows readily on peptone media under aerobic conditions, and will also grow in an agar shake at all depths. It grows readily at 37°C., and more slowly, although eventually more luxuriantly, at 22°C. Under conditions of strict anaerobiosis no visible growth occurs.

Peptone Agar. Good growth is obtained in 24 hours at 37°C. A streak culture shows an even, raised, convex growth, somewhat yellowish in colour. Isolated colonies are regular in outline, raised, opaque, somewhat glistening, and convex to pulvinate, and reach a diameter of up to 1 mm. After 48 hours' incubation the colony becomes more irregular in outline, less raised, and more tenacious. Confluent growth shows more irregularities, with piling up of the

growth where inoculation has been heavier. When the agar is moist and growth is rapid, following several subcultures, the confluent growth is usually moist and mucoid, and quite distinct from the dry, tenacious growth of less active cultures. The yellowish colour of the growth is more apparent after 48 hours' incubation. Surface colonies do not tend to spread, nor do they develop a filamentous appearance. Colonies develop well in deep agar, and reach a diameter of from 0·5 to 0·75 mm. in 48 hours. Under the microscope they are seen to be filamentous, with a branching mycelial extension at the periphery. (Figures 7 and 9.) There is no development of aerial hyphae.

At 22°C. growth is slower, and it is usually 72 hours before it is apparent. A streak inoculation gives rise to a raised and wrinkled growth, more massive than that obtained at 37°C. Many lumpy, rounded, elevated masses develop on the surface of an agar slant inoculation, and sometimes the growth is slightly wrinkled. (Figure 4.) At the lower temperature the colour of the growth is more fully developed. This agrees closely in hue with antimony-yellow, but more exactly to hue 16′, tone b (Plate XV, Ridgway, "Colour Standards and Nomenclature"). There is no colour imparted to the agar medium. Surface colonies, instead of taking on the rounded, pulvinate form usually seen in rapidly growing cultures at 37°C., are flatter, with an umbonate centre and raised, lobate-lobulate margins. (Figure 10.)

Glucose Agar. Growth is the same as on peptone agar.

Blood Agar. Deep blood-agar plates show good colony development in 48 hours at 37°C., with a clear zone of haemolysis, 3·5 mm. in diameter, around the colonies.

Loeffler's Blood Serum. Good growth occurs, but is somewhat more tenacious than on peptone agar. There is no evidence of any digestion after 10–14 days' incubation at 37°C.

Gelatin. Growth is not so good as on peptone agar. Liquefaction only occurs when the reaction is adjusted to the alkaline side of neutrality, a pH 7·6 being suitable. A stab culture incubated at 22°C. shows commencing liquefaction in six days. The liquefaction is saccate in type, and develops to a depth of 1 cm. in fourteen days. At 37°C. liquefaction is incomplete at the end of six days and complete in nine days. If equal quantities of milk and gelatin are used liquefaction is more rapid, being complete within six days.

Potato. No visible growth occurs on potato.

Peptone Broth. Good growth occurs at 37°C., with the formation of a pellicle in 24 hours. There is no general clouding of the medium. Sometimes the pellicle is soft, and at other times more tenacious. Growth often occurs at the sides of the tube, producing a frosted appearance on the glass. There is usually a slight sediment, which is more abundant when the pellicle falls. On continued incubation the sediment may become mucoid in character. When growth is less vigorous there is no pellicle formation, and discrete colonies

develop and attach themselves to the sides and bottom of the tube. When inoculation is light, and incubation is at 22°C., a filamentous colony may occur in the depth of the medium.

Litmus Milk. The colour is bleached in four days, and the medium completely digested in from seven to eight days. The characteristic yellow colour is imparted to the medium. At no time is there any definite coagulation. The digestion is from the surface downwards, and the undigested milk at the bottom of the tube appears to be slightly granular in appearance.

Brom-cresol Purple Milk. Digestion is complete in from seven to eight days, with the production of an increasing alkaline reaction. Ammonia appears to be produced, as the addition of permutit to the medium prevents the full development of the colour change of the indicator.

Fermentation Reaction. Glucose and laevulose are fermented in 48 hours, with the production of acid but no gas. Glycerine is fermented more slowly, only a low acidity resulting. No change is produced in maltose, galactose, saccharose, lactose, mannite, dulcite, dextrin, raffinose, arabinose, adonite, inulin, sorbite, salicin, amygdalin, or erythrite. No diastatic action is demonstrable in broth containing 1% of "soluble starch," but the starch is partly hydrolyzed, with the production of erythro-dextrin, but no acid. Urea is fermented with the production of an alkaline reaction.

Nitrate Reduction. No reduction of nitrates can be demonstrated. It has been necessary to carry out the cultivation in a sealed, moist chamber, to prevent the absorption of nitrous fumes from the air.

Indol is not produced.

The Proteolytic Enzyme. There is rapid digestion of casein, but no action has been demonstrated on coagulated blood serum, coagulated egg white, or on fibrin. The ferment is active only in an alkaline medium. It appears to agree with other proteolytic enzymes of bacterial origin in the production of ammonia. No attempt has been made to study this enzyme more completely, but sufficient information has probably been obtained to assist in the identification of the micro-organism.

Pathogenic Action. The micro-organism produces no lesions in rabbits or guinea-pigs when injected intravenously or intraperitoneally. Subcutaneous inoculation leads to local abscess formation. Lesions are produced when an emulsion of the organism is swabbed on the skin after the hair has been pulled out. No lesions are produced if the culture is applied to the uninjured skin, but the pulling out of the hair produces sufficient injury to allow the micro-organism to invade the skin. In 24 hours there is erythema, and the epithelium around the follicles becomes opaque, producing a finely speckled appearance. In 48 hours the skin is thickened, and a sero-fibrinous exudate appears on the surface. The exudate accumulates during the next few days, but the reaction gradually subsides, and resolution occurs in eight to ten days in the guinea-pig and in

fourteen days in the rabbit. The white mouse reacts in much the same way as the rabbit and guinea-pig, but the skin lesions are milder and more chronic.

The skin of the cow and the horse is also susceptible to invasion following superficial scarification. A more severe reaction develops in the horse, the lesion being very desquamative.

Classification and Nomenclature. A consideration of the morphology and cultural characteristics leaves little doubt that the micro-organism belongs to the genus *Actinomyces.* Although the terms Streptothrix and Nocardia have been suggested for many branching, filamentous micro-organisms, the general consensus of opinion is that they should be grouped under the general heading of actinomyces, for the present at least.

The micro-organism appears to be a new species, and the name *Actinomyces dermatonomus* is suggested for it.

DISCUSSION.

The lesion, found in sheep under natural conditions, and produced in sheep and other animals under artificial conditions, is to be classed as a dermatomycosis. It resembles in many respects ringworm, or trichophytosis, of man and the lower animals. One remarkable feature of the disease is the absence of lesions on the more exposed surfaces of the body, except in rare cases, as a secondary manifestation. If the disease were passed on by direct contact one might expect lesions on those parts which naturally are free from wool. To reach the skin on the back and the sides of the animal the micro-organism has to penetrate the thick fleece of wool. It appears from the data collected that the micro-organism probably grows in the fleece when conditions, such as moisture, are favourable. The numerous and scattered lesions suggest that colonies develop in the fleece, and the growth extends between the wool fibres to the skin. The uninjured skin does not offer as favourable conditions for invasion as skin which has been slightly injured or abraded. As moisture favours the growth of micro-organisms in the fleece, it is possible that after rain moisture travelling down the wool fibres to the skin causes some softening of the superficial epithelium which would favour the invasion by the actinomyces. Moisture possibly has a twofold action, therefore, in favouring the growth of the micro-organism and causing superficial softening of the epithelium. As for the most part only young animals are attacked, it would appear that the skin of older animals offers greater resistance to invasion. It is suggested that this species of actinomyces leads a saprophytic existence in the fleece of sheep, and that occasionally conditions become favourable to its invasion of the skin. Although moisture in the fleece is possibly an essential factor in the production of lesions, excessive moisture does not appear to be necessary, as the rainfall during the winter of 1928 was below the average, and the disease was more severe than had been previously experienced.

Biting insects can be excluded as playing any part in the transmission of the disease or the production of lesions in the present investigation.

SUMMARY.

A dermatomycosis, due to a species of *Actinomyces*, affecting young merino sheep, is described.

Although the disease is rare, and only one or two animals may be affected, in some flocks it may on occasion affect over 20% of the young animals.

The cultural characteristics of the causal micro-organism, which has been named *Actinomyces dermatonomus*, are described.

Preventive methods for the control of the disease are suggested.

I am indebted to Professor J. A. FitzHerbert, of the University of Adelaide, for assistance in the choice of the specific name suggested for the micro-organism, and to Dr. Ethel McLennan, Botany Department, the University of Melbourne, for the opinion that the micro-organism belongs to the Actinomycetes.

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DESCRIPTION OF PLATES.

Figure 1. Sheep L. 1, showing well-developed lesions over the skin of the nose, around nostrils, and extending from the corners of the mouth under the chin.

Figure 2. Sheep L. 2, showing the development of lesions about the lips.

Figure 3. A mass of matted wool removed from sheep L. 1. This has apparently resulted from two lesions coalescing which is suggested by the slight constriction in the centre of the mass. Note the deep concave surface at the base of the mass. The mass is photographed in the reverse normal position. Scale in inches.

Figure 4. Culture of *Actinomyces dermatonomus* on peptone agar incubated at 22° C. for 14 days. Note the piled up, bullate, and slightly wrinkled, rugose appearance of the growth. × 1·5.

Figure 5. Microscopic appearance of a stained smear of a rapidly growing 24 hours' old culture of *Actinomyces dermatonomus*. Note the mycelium breaking up into conidia and the relatively large number of conidia present.

Figure 6. Smear of another young culture of *Actinomyces dermatonomus* showing the presence of bacillary forms and conidia. Many of the bacillary forms are swollen and somewhat bent at one end.

Figure 7. A deep colony of *Actinomyces dermatonomus* in peptone agar showing the filamentous character of the colony. × 94.

Figure 8. Surface colonies of *Actinomyces dermatonomus* on peptone agar. Primary growth. Note the smooth, pulvinate character of colony. × 1·5.

Figure 9. Edge of the same deep colony as shown in Figure 7 under higher magnification showing the branching mycelium. × 180.

Figure 10. Deep and surface colonies of *Actinomyces dermatonomus*. The deep colonies are small, the surface colonies are umbonate with a raised, lobate-lobulate edge. This type of surface colony may occur under conditions of slow development at 22° C. × 1·5.

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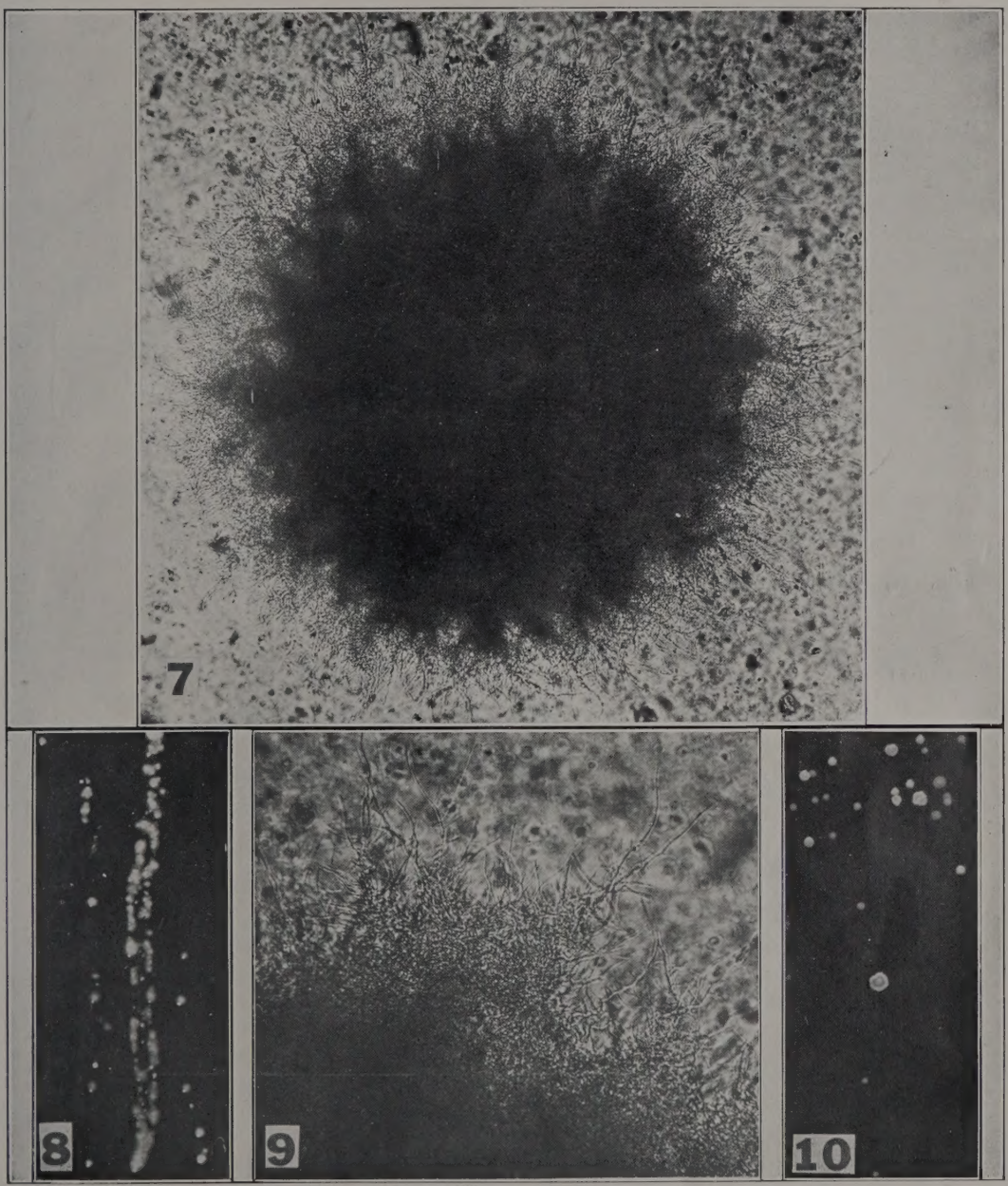
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